APPENDIX G

Data Quality Objectives for the Tittabawassee River and Floodplain Remedial Investigation

The purpose of the Tittabawassee River and Floodplain Remedial Investigation (RI) is to assess site conditions and then select an appropriate remedial action, if one is required, that adequately addresses those conditions. The type and quality of data needed to satisfy the different objectives of the RI are governed by the data quality objectives (DQOs). Specific DQOs have been defined for the sampling and data evaluation activities that are the focus of Phase I of the RI. The problem statements and sources of data to satisfy each DQO are identified by phase in Table 4-1 of the Tittabawassee River and Floodplain Remedial Investigation Work Plan (RIWP) main document. This appendix provides a complete description of the decision rules associated with each of the RI problem statements, and explains the rationale for the various sampling programs that will be performed during Phase I of the RI.

Data Quality Objectives Process

The DQO process is a planning tool used to avoid collecting data that are inconsequential to decisionmaking, and to ensure that data of sufficient quantity and quality are collected so that informed decisions can be made. In this manner, DQOs minimize expenditures related to data collection by eliminating unnecessary, duplicative, or overly precise data. DQOs ascertain the type, quality, and quantity of data necessary to address the problem before sampling and analysis begin. The EPA guidance document, *Guidance for the Data Quality Objectives Process* (USEPA, 2000) outlines a seven-step process for establishing DQOs. These steps are as follows:

- **State the problem.** Concisely describe the problem to be solved: background information and what information is missing.
- **Identify the decision.** Identify the decision that must be made to resolve the problem.
- **Identify the inputs to the decision.** Identify the information or data needed to make the decision.
- **Define the study boundaries.** Specify the conditions (time periods, spatial areas and situations) to which the decision will apply and within which the data will be collected.
- **Develop a decision rule.** Define the conditions by which the decisionmaker will choose among alternative risk management actions. This is usually specified in the form of an "if. . . then . . ." statement.
- **Specify acceptable limits on decision errors.** Define the decisionmaker's acceptable uncertainty based on the consequence of making an incorrect decision.

- **Optimize the sampling design.** Evaluate the results of the previous steps and develop the most resource-efficient design for data collection that meets all of the DQOs.

Phase I Remedial Investigation Data Quality Objectives

The DQO problem statements that support the investigation approaches discussed in Section 4 of the RIWP are as follows:

- **DQO 1:** Identify the potential constituents of interest (PCOIs) that may have been released to the Tittabawassee River due to operations at The Dow Chemical Company (Dow) Midland Plant, Midland MI (Midland Plant).
- **DQO 2:** Characterize the distribution of PCOIs in sediment and floodplain soil, as follows:
  - 2a: Characterize horizontal distribution of polychlorinated dibenzo-p-furans (furan) and polychlorinated dibenzo-p-dioxins (dioxin) and other PCOIs in sediment.
  - 2b: Characterize vertical distribution of furans and dioxins and other PCOIs in sediment.
  - 2c: Characterize the lateral extent of furans and dioxins and other PCOIs in floodplain soil.
  - 2d: Characterize horizontal distribution of furans and dioxins across floodplain based on geospatial model.
  - 2e: Characterize horizontal distribution of other PCOIs in floodplain soil.
  - 2f: Characterize vertical distribution of furans and dioxins and other PCOIs in floodplain soil.
- **DQO 3:** Characterize fate and transport mechanisms in the river and floodplain.

The outcomes of the DQO process for these problem statements are summarized in Tables G-1 through G-8. DQOs related to additional sampling objectives that may arise during the course of the RI will be developed after the Phase I sampling, analysis, and data evaluations are completed and as the RI progresses.

Statistical Basis for Sample Sizes

The appropriate method for determining the sample size depends on the applicable decision rule, the type of statistical test being performed, and the required level of certainty associated with the conclusions. Tables G-1 through G-8 provide a description of the specific decision rules associated with the Phase I DQOs. The tables also describe the required sample sizes and give a brief description of the basis for the sample sizes. This section provides more background related to sample size calculations.

The primary method for determining the appropriate sample size for Phase I soil and sediment sampling, which is applicable in cases where the decision rule involves estimating population quantiles, involves determining the sample size required to the estimate a nonparametric (distribution-free) prespecified tolerance interval with a prespecified level of confidence (Conover, 1980). This method assumes that samples will be collected within areas of relatively homogeneous properties. The number of samples determined using this method is independent of the size of the area and makes no assumptions about the underlying distribution of the chemical, compound, or physical property. However, the method requires specification of both a desired level of confidence and a desired upper bound on the quantile being estimated. The level of confidence reflects the probability that the maximum level from a sample of a given size will exceed the quantile of interest, and is pre-selected. The quantile also is preselected and represents the proportion of the population being estimated. For example, half of the population is greater and half of the population is less than the 0.5 quantile.

The formula for computing the number of samples required to be able to estimate a prespecified quantile (q), with a prespecified level of confidence (p) is as follows:

$$n = \frac{\ln(1-p)}{\ln(1-q)}$$

For example, to have 95 percent confidence that the maximum value represents at least the 0.95 quantile, a sample size of 59 is required. To have 80 percent confidence that the maximum value represents at least the 0.95 quantile, a sample size of 32 is required. To have 99 percent confidence, a sample size of 90 is needed.

The only strong assumption implicit to the nonparametric tolerance interval methodology is that sampling is randomized. Randomization means that any location carries an equal probability of being sampled and that sampled locations are randomly assigned. It is protection against potential bias in results caused by unknown processes. Although an essential component to a sampling strategy, complete randomization is not the most efficient way to assign sample locations. A useful constraint to randomization in environmental situations where spatial coverage is of interest is to systematically sample from a randomized start point. This means that all of the points in the area to be characterized carry equal probability of being sampled, but that the entire area is uniformly sampled. Examples include collecting samples along equally spaced transects, with a randomized start-point.

References

CH2M HILL. 2004. Nonanalytical Sampling Activities for Tittabawassee River. November.

Conover, W. J. 1980. *Practical Nonparametric Statistics.* New Jersey: John Wiley.

Michigan Department of Environmental Quality (MDEQ). 2002. Sampling Strategies and Statistics Training Materials for Part 201 Cleanup Criteria.

U.S. Environmental Protection Agency (USEPA). 2000. Data Quality Objectives for Hazardous Waste Site Investigations. EPA QA/G-4 HW, EPA/600/R-00/007.

Table G-1
DQO 1: PCOI Identification

Problem Statement	Identification of PCOIs is a requirement for characterization of the nature and extent in both the Operating License and in Condition 201 (for example see Michigan Administrative Code Rule 299.5528).
Decision to be Made	What are the PCOIs to be used in the nature and extent evaluations?
Inputs to the Decision	• Target analyte list (TAL) • Generic human and ecological benchmark values for TAL chemicals • Sediment, soil, and surface water samples collected from upstream reference areas to establish background threshold values for TAL chemicals that are not eliminated by initial comparisons to benchmark values and spatial trend analysis. • Historical data for TAL chemicals • Sediment, soil, and surface water samples analyzed for TAL chemicals
Study Boundaries	**Reference Area Background Threshold Values** – Upstream locations, beyond influence of Dow Midland Plant **PCOI Identification** • Longitudinal boundary: Dow Midland Plant to 25 miles downstream (excluding portions of floodplain on Dow Midland Plant) • Lateral boundary: 100-year Floodplain • Vertical boundary: Base of unconsolidated sediment, base of floodplain deposits, base of surface water column
Decision Rules	Decision rules for PCOI screening will be developed separately for human health and ecological risk assessments. The lists of human health and ecological PCOIs for all media will be combined to become the list of PCOIs for the soil and sediment nature and extent evaluations. Background concentrations from suitable reference areas will be needed only if initial comparison of PCOI sample data to generic benchmark values and spatial trend analysis indicate that elevated concentrations of TAL chemicals may be related to natural or anthropogenic background**.** The detailed approach for the use of background in the PCOI determination process will be determined by the ecological and human health risk assessors. It is anticipated that the comparison may involve the development of 95 percent Upper Prediction Limits (UPLs) for each target analyte, which are statistically derived confidence bounds that are 95 percent certain to contain all possible background results and are described in Michigan Department of Environmental Quality (MDEQ) guidance (*Sampling Strategies and Statistics Training Materials for Part 201 Cleanup Criteria* [MDEQ, 2002]). In this case, it is anticipated that individual study area sample results will be compared to the reference levels and/or benchmarks. Another potential approach is to perform a two-sample means comparison between study area samples and background concentrations. This approach also is described in MDEQ guidance.
Acceptable Limits on Decision Errors	**Reference Area Background Threshold Values** - Based on the anticipated calculation of UPLs, the sampling design for establishing reference area background threshold values needs to support the calculation of 95 percent UPLs. Assuming that the data follow neither a normal nor lognormal distribution, the UPL may need to be computed based on nonparametric methods. In this case, then 30 samples provide approximately 80 percent certainty that the highest observed value will represent at least the 95th percentile, or 95 percent certainty that the highest value will represent the 90th percentile. Thirty (30) samples also are generally accepted to support means comparisons. **PCOI Identification** - The sampling design for PCOI identification needs to be robust enough to support use in risk screening. For sample size selection purposes, a 95 percent confidence interval on the 95th quantile relative to benchmark values was identified as an acceptable limit on decision errors. This means that if the population of samples in the data set has a benchmark exceedance rate of 5 percent or higher, there is a 95 percent chance of observing at least one exceedance. A minimum of 59 samples are required to achieve this tolerance level.
Optimized Sampling Design	**Reference Area Background Threshold Values -** The data set for establishing background threshold values will be composed of soil, sediment, and surface water samples, because each of these media has the potential to contain different target analytes. Background threshold values for each media will be calculated using the following sample sets obtained in an upstream reference area: 30 surface soil samples, 30 subsurface soil samples, 30 surface sediment samples, 30 subsurface sediment samples, and four surface water samples (30 samples of surface water are not required because surface soil is a transient medium and flow-integrated samples from multiple events will be collected). Soil samples will be obtained from regularly spaced locations (that is, grid) at the Chippewa Nature Center and Emerson Park. Sediment samples will be obtained from regularly spaced locations (that is, transects) along the Chippewa and Upper Tittabwassee Rivers adjacent to the Chippewa Nature Center and Emerson Park. Surface water samples will be collected from the Chippewa and Upper Tittabwassee Rivers. Surface water samples will be collected during normal Spring flow and during a high water event. **PCOI Identification -** The data set for PCOI identification will be composed of soil, sediment, and surface water samples, as each of these media has the potential to contain different concentrations and distributions of target analytes. Existing soil and sediment results for TAL chemicals will be considered in the evaluation, as appropriate. The following additional samples will be collected from the study area: ***Soil:*** 60 sample locations distributed throughout the 100-year Floodplain. One surface soil sample (from the 0 to 0.5 foot interval) will be collected at each location. One subsurface soil sample also will be collected at each location. The subsurface soil samples will be obtained from randomly determined subsurface soil intervals (that is, greater than 0.5 feet below ground surface [bgs]) within recent floodplain deposits (that is, not glacial deposits) at each sample location. ***Sediment:*** 25 sample locations distributed along regularly-spaced transects along length of study area. One surface sediment sample from 0 to 0.5 foot will be collected at each location. One to 3 subsurface samples (for a total of 25 to 75 subsurface sediment samples) will be collected at each location, depending on thickness of unconsolidated sediment at each location. ***Surface Water:*** A total of 6 samples consisting of flow-integrated samples collected at three locations along the river during normal spring flow and during a high flow event. The samples will be divided into dissolved and suspended solids fractions for analysis.

Table G-2
DQO 2a – Characterize Horizontal Variability of Furans and Dioxins and Other PCOIs in Sediment

Problem Statement	The results from the Tittabawassee River and Floodplain Scoping Study (Scoping Study) and historical sample results indicate the spatial distribution of furan and dioxin concentrations in the sediment follows a random pattern on all scales, with an absence of trends and or locally sustained elevated concentrations. Additional sediment data are needed to confirm these earlier results concerning spatial distribution of furans and dioxins in sediments, and to evaluate the spatial distribution of other PCOIs in sediment.
Decision to be Made	What is the horizontal distribution of furans and dioxins and other PCOIs in sediment?
Inputs to the Decision	• PCOI sediment samples (see DQO 1) • Historical sediment samples • PCOI list (see DQO 1)
Study Boundary	• Longitudinal boundary: Dow Midland Plant to 25 miles downstream • Vertical boundary: Upper 0.3 feet of sediment
Decision Rules	Based on the Scoping Study and historical data results, the spatial distribution of furan and dioxin concentrations in sediment follow a random pattern. As a result, it is expected that the "statistical distribution" of furan and dioxin concentrations can be characterized by a single set of summary statistics, including the mean, median, standard deviation, range, and percentile estimates. If the sediment data collected from the entire length of the river verify the expected pattern of distribution for furans and dioxins, all surface sediment furan and dioxin results will be combined to compute summary statistics to characterize the surface sediment concentrations. These data will be used as input into risk assessment and to identify remedial alternatives. If the pattern of furan and dioxin concentrations suggests that there is a spatial trend, then additional sampling during Phase II may be required to support risk assessment or remedial action decisions. If the pattern of concentrations for other PCOIs suggests that there is a spatial trend for these analytes, then additional sampling during Phase II may be required to support risk assessment or remedial action decisions.. Otherwise, summary statistics for other PCOIs in the surface sediment will be computed in the same way as for furans and dioxins.
Acceptable Limits on Decision Errors	Collect a sufficient number of sediment samples to provide coverage of the entire study area and also to be able to estimate the mean concentration to within plus or minus 50% if the standard deviation.
Optimized Sampling Design	Historical sample results and results for the PCOI identification samples will be used to evaluate the distributions of furans and dioxins and other PCOIs in sediment.

Table G-3
DQO 2b – Characterize Vertical Distribution of Furans and Dioxins and Other PCOIs in Sediment

Problem Statement	The results from the Scoping Study and historical sample results indicate the vertical distribution of furan and dioxin concentrations in the sediment follows a random pattern on all scales, with an absence of trends and or locally sustained elevated concentrations. Additional sediment data are needed to confirm these earlier results concerning vertical distribution of furans and dioxins in sediments, and to evaluate the vertical distribution of other PCOIs in sediment.
Decision to be Made	What is the vertical distribution of furans and dioxins and other PCOIs in sediment?
Inputs to the Decision	• PCOI sediment samples (see DQO 1) • Historical sediment samples, including scoping study sediment samples • PCOI list (see DQO 1)
Study Boundary	• Longitudinal boundary: Dow Midland Plant to 25 miles downstream • Vertical boundary: Base of unconsolidated sediment
Decision Rules	Based on the Scoping Study and historical data results, the vertical distribution of furan and dioxin concentrations in the sediments is believed to be randomly distributed throughout the sediment but the concentrations below the surface are generally lower than those at the surface. If the sediment data collected from the entire length of the river verify the expected pattern of vertical distribution for furans and dioxins, all subsurface sediment furan and dioxin results will be combined to compute summary statistics (mean, median, standard deviation, percentile estimates) to characterize the subsurface sediment concentrations. These data will be used as input into risk assessment and to identify remedial alternatives. If the pattern of furan and dioxin concentrations suggests that the vertical distribution is different from what is expected, then additional sampling during Phase II may be required to support risk assessment or remedial action decisions. If the pattern of concentrations for other PCOIs suggests that there is a spatial trend or that the vertical distribution differs from that for furans and dioxins, then additional sampling during Phase II may be required to support risk assessment or remedial action decisions. Otherwise, summary statistics for other PCOIs in the subsurface sediment will be computed in the same way as for furans and dioxins.
Acceptable Limits on Decision Errors	Collect a sufficient number of subsurface sediment samples to provide coverage of the thickness of unconsolidated sediment along the entire study area and also to be able to estimate the mean concentration to within plus or minus 50 percent of the standard deviation.
Optimized Sampling Design	Historical sample results and results for the PCOI identification samples will be used to evaluate the vertical distributions of furans and dioxins and other PCOIs in sediment.

Table G-4
DQO 2c – Lateral Extent of Furans and Dioxins in Floodplain Soil

Problem Statement	The results from the Scoping Study indicate that furan and dioxin concentrations outside the 8-year Floodplain boundary are significantly lower than concentrations inside the 8-year floodplain boundary. Additional soil data from areas outside the 8-year Floodplain soils are needed to confirm that the 8-year Floodplain represents a boundary for lateral extent of furans and dioxins .
Decision to be Made	What is the lateral extent of furans and dioxins in floodplain soil?
Inputs to the Decision	• PCOI soil samples (see DQO 1) • Historical soil samples • Scoping Study soil samples • Surface soil samples obtained outside of the 8-year Floodplain •
Study Boundaries	• Longitudinal boundary: Dow Midland Plant to 25 miles downstream (excluding portions of floodplain on Dow Midland Plant) • Lateral boundary: 100-year Floodplain • Vertical Boundary: Upper 6 inches of soil
Decision Rules	If furan and dioxin concentrations (normalized to TEQ) in samples located outside of the 8-year Floodplain boundary are less than 90 ppt, then the lateral extent of furans and dioxins will be considered bounded by the 8-year Floodplain boundary. Otherwise additional sampling beyond the 8-year Floodplain boundary may be required during Phase II to define lateral extent.
Acceptable Limits on Decision Errors	Enough samples should be collected to be able to estimate the likelihood (or proportion) of exceeding the benchmark values to within plus or minus 5 percent.
Optimized Sampling Design	A minimum of 60 additional samples should be collected from locations approximately 20 to 50 feet outside of the 8-year Floodplain; 20 samples will be located outside of the 8-year Floodplain boundary in the northern portion of the study area where there is a distinct valley wall marking the edge of the floodplain, and 40 samples will be located outside of the 8-year Floodplain boundary in the southern portion of the study area where the 8-year Floodplain boundary diverges from the 100-year Floodplain boundary.

Table G-5
DQO 2d – Develop Geospatial Model for Furan and Dioxin Distribution in Floodplain Soil

Problem Statement	The Scoping Study results suggest that concentrations of furans and dioxins in floodplain soil are driven by solids-mediated transport during flooding events. Patterns of deposition suggest migration of solids from in-river to proximal floodplain areas under flooding conditions, resulting in the formation of floodplain geomorphic features such as levees, point bars, and splays. These features exhibit differences in grain size distribution and appear to show elevated furan and dioxin concentrations that are likely related to historical transport of solids from the river to the floodplain. The locations of these floodplain structures are predictable based on hydrodynamic modeling. Consequently, it appears that the distribution of furans and dioxins, throughout the floodplain can be predicted accurately using a combination of hydrodynamic modeling, influencing factors, and geostatistical analysis. Additional sampling and data evaluation are needed to develop a preliminary geospatial model. The results for previously collected samples, including other Phase 1 soil samples, will then be used to test and refine the preliminary model so that it is capable of predicting concentrations throughout to floodplain.
Decision to be Made	Predict furan and dioxin concentrations in floodplain soils based on geospatial model
Inputs to the Decision	• PCOI soil samples (see DQO 1) • Historical soil samples • Scoping Study soil samples • Additional Scoping Study area samples, including completion of scoping study grid and transect sampling at Area 3 and the Confluence Area and cluster sampling at geomorphic feature sampling in scoping study areas • Hydrodynamic modeling
Study Boundary	• Longitudinal boundary: Dow Midland Plant to 25 miles downstream (excluding portions of floodplain on Dow Midland Plant site) • Lateral boundary: As determined in DQO 2c • Vertical Boundary: Upper 6 inches of soil
Decision Rules	A specific decision rule is not required for evaluation of the geospatial model. Existing and Phase I sample results will be evaluated in the context of the preliminary model developed from the Scoping Study area data to determine whether the model accurately predicts furan and dioxin concentrations elsewhere in the study area. Additional sampling will be conducted during Phase II of the RI to further validate the model and/or support risk assessment or remedial alternative development.
Acceptable Limits on Decision Errors	The geospatial model needs to be sufficiently robust to predict furan and dioxin concentrations throughout the floodplain at the levels of resolution required for human and ecological risk assessment.
Optimized Sampling Design	**Completion of Scoping Study at Area 3 and Confluence Area -** Area 3 and the Confluence Area represent areas where hydrodynamic conditions may be different than those observed during the Scoping Study. To verify that the conceptual site model holds in these areas and/or refine the model, samples will be collected from a 400-foot grid in Area 3 and from two mutually perpendicular transects (400- to 800-foot spacing) in the Shiawassee Wildlife Refuge portion of the Confluence Area. Surface soil will be collected from all previously unsampled locations in Area 3 (32 locations) and the Confluence Area (11 locations). **Cluster Sampling at Geomorphic Features in Areas 1, 2, and 3 -** To support the small-scale variability characterization (that is, semivariogram analysis), stratified sampling will be performed in Areas 1, 2, and 3. Up to four geomorphic features will be identified from hydrodynamic modeling in each Scoping Study area. Twenty surface soil samples will be collected from mutually perpendicular transects centered over each feature. Samples will be spaced along the transects at half-log distances proportional to the expected size of the feature.

Table G-6
DQO 2e – Characterize Lateral Distribution of Other PCOIs in Floodplain Soil

Problem Statement	The lateral distribution of PCOIs, other than furans and dioxins, in floodplain soil is unknown. Additional soil samples are needed to determine whether the distribution of these PCOIs are similar to that of furans and dioxins
Decision to be Made	Characterize the lateral distribution other PCOIs in floodplain soils
Inputs to the Decision	• PCOI soil samples (see DQO 1) • Historical soil samples • PCOI list (see DQO 1) • Part 201 cleanup criteria and reference area background UPL values (background UPL to be used as comparison value if greater than Part 201 value) for PCOIs • Dioxin and furan geospatial model (see DQO 2d)
Study Boundary	• Longitudinal boundary: Dow Midland Plant to 25 miles downstream (excluding portions of floodplain on Dow Midland Plant site) • Lateral boundary: As determined in DQO 2c • Vertical Boundary: Upper 6 inches of soil
Decision Rules	If the distribution patterns and relations in surface soil for other PCOIs are similar to those of furans and dioxins, then the geospatial model developed for furan and dioxin distribution can also be used for other PCOIs. Otherwise, additional sampling may be needed to characterize the lateral extent and distribution of other PCOIs.
Acceptable Limits on Decision Errors	A sufficient number of surface samples must be collected to ensure that the results are representative of the entire floodplain, including areas of high and low concentrations.
Optimized Sampling Design	Historical sample results and results for the PCOI identification samples will be used to evaluate the distribution other PCOIs in surface soil.

Table G-7
DQO 2f – Characterize Vertical Extent of Furans and Dioxins and Other PCOIs in Floodplain Soil

Problem Statement	The results of the Scoping Study suggest that subsurface soil samples taken from cores closest to the Tittabawassee River have the highest furan and dioxin concentrations and have thicker horizons of furans and dioxins in soil. Locations with thicker sequences of furans and dioxins also tend to correspond to levees and point bars where larger volumes of material are deposited during high water events. With increasing distance away from the river, elevated furan and dioxin concentrations appear to be confined to the upper 2 to 3 feet of soil. The vertical extent of other PCOIs is unknown. Additional subsurface soil samples are needed to characterize the vertical extent of furans and dioxins in portions of the floodplain that were not sampled and to determine the vertical extent of other PCOIs in floodplain soil.
Decision to be Made	Determine the vertical extent of furans and dioxins and other PCOIs in floodplain soils
Inputs to the Decision	• PCOI soil samples (see DQO 1) • Historical soil samples • Scoping Study soil samples • PCOI list (see DQO 1) • Part 201 cleanup criteria and reference area background UPL values (background UPL to be used as comparison value if greater than Part 201 value) for PCOIs • Additional Scoping Study area samples, including completion of Scoping Study grid and transect sampling at Area 3 and the Confluence Area and subsurface soil sampling at geomorphic feature sampling in Scoping Study areas • Hydrodynamic modeling
Study Boundary	• Longitudinal boundary: Dow Midland Plant to 25 miles downstream (excluding portions of floodplain on Dow Midland Plant site) • Lateral boundary: As determined in DQO 2c • Vertical Boundary: Base of floodplain deposits
Decision Rules	Subsurface soil sampling results from existing and Phase I investigations will be evaluated to determine whether the depth of furans, dioxins, and other PCOIs follow a predictable pattern or can be explained through estimated accretion rates or other influencing factors such as geomorphic features or evidence of historical disturbance. Additional subsurface sampling may be conducted during Phase II of the RI to further delineate vertical distributions at specific locations to support risk assessment and/or remedial action alternative development. The results from subsurface soil samples will be compared point by point with Part 201 cleanup criteria or background UPL values (background UPL will be used if it is higher than Part 201 value). The vertical extent of furans, dioxins, and other PCOIs in soil will be considered bounded where concentrations are lower than the Part 201 criteria or background UPL, as appropriate. If necessary, separate vertical extent decisions will be made for the different study areas.
Acceptable Limits on Decision Errors	A sufficient number of subsurface samples must be collected to ensure that the results are representative of the entire floodplain, including areas of high and low concentrations. To show that the vertical boundary has been delineated, the goal is to establish at least 95 percent confidence that concentrations at the vertical boundary and beyond are less than the Part 201 criterion at least for furans and dioxins. Assuming that the data are consistent across all sampling areas and that at least three consecutive results per boring are below Part 201 criteria or reference area background UPLs, a total of 28 vertical sampling locations (distributed across the five study areas) is expected to provide sufficient data to provide 95 percent confidence that the 95th percentile of concentrations below a given depth level have been characterized. If vertical extent is not consistent across areas or across borings within an area, additional samples may be required. In addition, the required limits on decision errors may need to be re-evaluated after the PCOI list has been determined.
Optimized Sampling Design	**Completion of Scoping Study at Area 3 and Confluence Area -** Subsurface soil samples will be collected at 2 locations in Area 3 and 5 locations in the Confluence Area. Subsurface soil samples will be collected every 0.5 feet for the upper 3 feet and every 1 foot thereafter until the glacial deposits are reached. **Vertical Extent Sampling at Geomorphic Features in Areas 1, 2, and 3 -** Four geomorphic features will be identified from hydrodynamic modeling in each Scoping Study area. Subsurface soil samples will be collected at 5 locations, with samples obtained every 0.5 feet for the upper 3 feet and every 1 foot thereafter until the glacial deposits are reached.

Table G-8
DQO 3– Characterize Potential for Redistribution of Furans and Dioxins and Other PCOIs

Problem Statement	Available information suggests that ongoing transport of furans and dioxins in the river and floodplain system is strongly affected by river-floodplain exchange processes. Preliminary hydrodynamic modeling performed to date shows a strong link between river-floodplain flow paths and the resulting distribution of furans and dioxins on the floodplain. Transport processes, including solids from the river bed to the floodplain depositional areas, solids within the floodplain due to event-driven resuspension and depositional processes, as well as the export of solids from the floodplain to the river, potentially affect the sequestration and/or redistribution of furans, dioxins and other particle-sorbed PCOIs in the river sediment or floodplain soil. A better understanding of these processes is needed to evaluate the potential effects of these processes on future risks, and on the permanence of potential remedies, if risk is identified.
Decision to be Made	Determine the effects of the following processes on PCOI fate and transport: • Association of furans and dioxins with particular grain size fractions • Input of clean sediment/solids from upstream of Midland and export of furans, dioxins, or other particle-sorbed PCOIs to the Saginaw River • Resuspension of sediment and redeposition as floodplain soil • Resuspension of floodplain soil and redeposition as sediment • Burial of soil or sediment containing furans, dioxins, or other PCOIs in depositional areas
Inputs to the Decision	• Analysis of grain-size fractionated soil and sediment samples for furans and dioxins • Measurement of flows and solids in the Tittabawassee River, including collection of surface water and suspended solids samples during a variety of flow events • Floodplain accretion and erosion studies, including dendrogeomorphic and geochronologic analysis, clay pad and turf mat studies, and bed and bank erosion studies. • Historic, Scoping Study, and Phase I sediment, soil, and surface water sampling results • Hydrodynamic modeling results
Study Boundary	• Longitudinal boundary: Dow Midland Plant to 25 miles downstream (excluding portions of floodplain on Dow Midland Plant site) • Lateral boundary: As determined in DQO 2c • Vertical boundary: Base of unconsolidated sediment, base of floodplain deposits, base of surface water column
Decision Rules	**Grain-size Association Evaluation -** The results from analyses of the fractionated soil and sediment samples will help identify the fraction of those matrices that are most critical to transport of furans and dioxins. **Flow and Solids Monitoring -** These data will be evaluated to identify if a difference in solids or furan, dioxin, or other PCOI loading is detected between the upstream and downstream boundaries. If little or no difference is detected, these processes may not be significant contributors to solids or furan, dioxin, or other PCOI loading downstream. If significant differences are observed between upstream and downstream boundaries, then additional focus may be placed on discriminating between different sources of load on the Tittabawassee (bed erosion, bank erosion, floodplain runoff). **Floodplain Accretion and Erosion Rate Studies -** The results from these studies will be used to identify accretion rates on the floodplain. If measured accretion rates are small or zero, resuspension processes may not be significant contributors to solids or delivery of furans, dioxins, or other PCOIs to the floodplain. If the observed solids load change is significant, accretion in the floodplain may be considered significant, and may play a role in determining the distribution of furans, dioxins, or other PCOIs in floodplain soils.
Acceptable Limits on Decision Errors	**Grain-size Association Evaluation –** Samples for grain-size fractionation should be collected from locations that are representative of sediment and soil at different hydrodynamically-influenced geomorphic features in the floodplain. **Flow and Solids Monitoring.** Flow and solids data must be representative of the range of flow events that convey solids to the river, including low-flow periods, annually recurring events, and less frequently occurring events (2-5 year recurrence). The data must also adequately represent the behavior of individual events, by capturing the rising limb, peak, post-peak, and tail of the hydrograph. The data must have sufficiently high temporal resolution to capture the rise, peak, and fall of the solids load that occurs in response to a wet-weather event. The data must be collected in a manner that captures the variability in flow and solids concentrations across the river cross-section. **Floodplain Accretion and Erosion Rate Studies -** Limiting decision errors involves assuring that data are collected in these studies in accordance with standardized methods.
Optimized Sampling Design	**Grain-size Association Evaluation -** Sample locations will be representative of observed geomorphic features, targeting four depositional features per study area and collecting three samples per feature. A fourth sample will be obtained from the river sediments upgradient from targeted depositional features in each area. Hydrodynamic model-generated streamlines will be used to identify upgradient locations. Each sample will be fractionated into three grain size classes: sands, silts, and clays. Gravels will be neglected as they were found to be a very small component of the particle size distribution in previous sampling, and are expected to play a minimal role in sorption of furans and dioxins. Samples will be analyzed for furan and dioxin congeners and TOC. **Flow and Solids Monitoring -** Existing data is available for a 7-10 year recurrence interval event, a 3-year recurrence interval event, and a 6-month event. Monitoring will be focused on capturing 1-2 events in the 6 month to 2-year recurrence interval range. Sampling will include high-frequency (1 hour) automated sampling at the upstream boundary of the study area to provide the required temporal resolution in the data. Bridge samples will be composited vertically-integrated volumes of water collected at stations along a subdivided transect of the river at each monitoring location. Samples will be collected using isokinetic sampling techniques, to ensure samples are representative of the entire river cross-section. Flow and solids monitoring will include composited vertically-integrated sampling in subsections of the river using isokinetic sampling techniques, to ensure representativeness of the entire river cross-section, and will target the rise, peak, and fall of the event hydrograph to ensure temporal representativeness. Monitoring will be focused on capturing 1 to 2 events in the 6 month to 2-year recurrence interval range, completing the range of events required to ensure representativeness of the range of Tittabawassee River flows. **Accretion and Erosion Rate Studies –** Additional dendrogeomorphic and geochronologic sampling and analysis will be conducted in Area3 and the confluence area. Monitoring will continue at the currently deployed clay pad and turf mat locations and the bed and bank erosion study locations (CH2M HILL, 2004).